Alternative Approaches to Closed Molding Infusion

Part One — History and Patents

By Scott Lewit

I began to work in the composites industry in 1987; I was hired by my graduate advisor Dr. Ron Reichard at my Alma-Ata, Florida Institute of Technology. It was in late 1987 that we formed Structural Composites, Inc. My first experiences with composites were all limited to the open molding process. In the late 1980's we had the great opportunity to help Hoechst Celanese with the development of Trevira for Composites. The work with Hoechst Celanese took us to manufacturers all over the United States and eventually into Europe. In the United States, I saw how RTM was being used to produce high volume parts. It was a fascinating process, but it was clear that most of the open molding industry could not make use of the technology. This was mostly due to the expense of tooling, the size scale of our parts, and limited volume production requirements of most open molded parts.

It was on the visits across Europe that I saw many innovative low cost approaches to closed molding. Europe already had strong environmental mandates in place and builders were already making use of low pressure RTM,

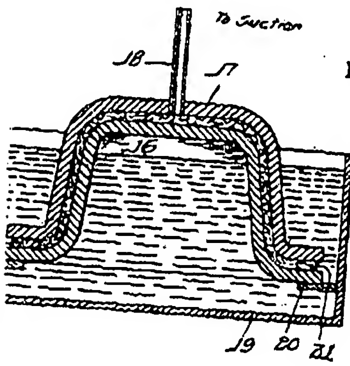

Fig 1

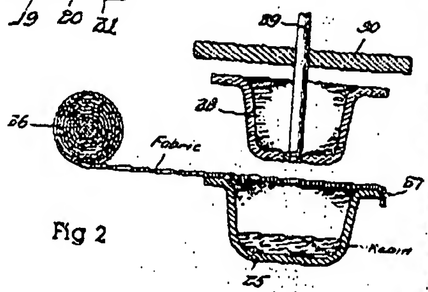

Fig 2

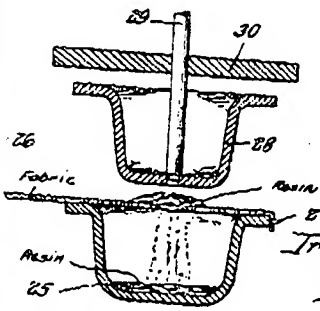

Fig 3

INVENTOR
Irving E. Muskat
BY
Schnider & Dressler
Atty

Nov. 17, 1959 G. H. SMITH 2,913,036

Filed Aug. 10, 1956 PROCESS AND APPARATUS FOR MOLDING LARGE PLASTIC STRUCTURES

2 Sheets-Sheet 1

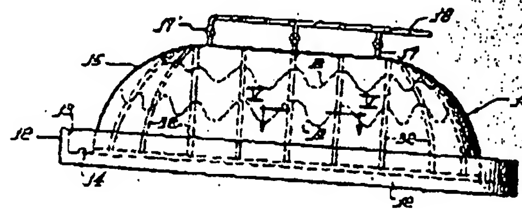

Fig 4

Another early patent I found interesting was by Smith, 1959 (Patent # 2,913,036). This patent is much more like today's modern infusion, in that it relies on a vacuum bag as a tool surface.

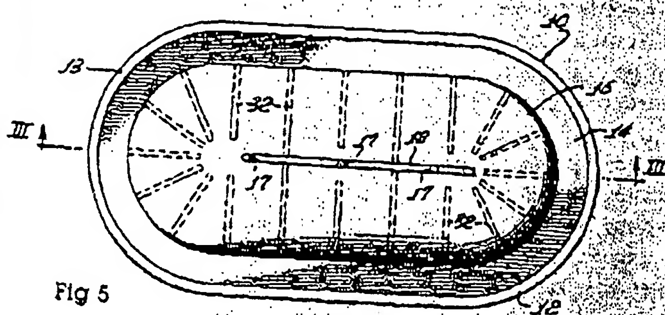

Fig 5

VARTM and variants of Infusion. In the early 1990's, European suppliers started to develop specialized material systems to make closed molding easier for builders. Europeans as well as Americans were performing RTM using continuous strand mat, but Europeans were starting to use combination reinforcements that employed an open porous spring-like neutral axis layer. This forced the higher fiber content reinforcement layer up against the tool surfaces and provided a pathway for resin (many times heavily filled) to be injected into the part.

In the United States in the early 90's we started hearing about a new patented process called SCRIMP (Seeman Composites Resin Infusion Molding Process). The process was producing high quality, high fiber content laminates and had attracted the attention of the US Navy. I found the SCRIMP concept to be very interesting, but due to the patent issues we decided to pursue open technology approaches to closed molding. Structural Composites, Inc. received funding from the Navy to develop a closed molding process we called recirculation molding, and off we went working on low cost matched tooling using VARTM. For the Navy's Mantech (Manufacturing Technology) program and the composites industry, we developed a low cost open technology. For the Navy, we produced and qualified composite rudders for Minehunters and fire hardened composite ducting systems.

A couple of years ago we started development work on a new synthetic media made by Colebond, called Enkamat. This material had the advantage of being able to maintain a pathway for resin flow that we found to help make VARTM and low pressure RTM much more effective. We also determined that the material would make an

excellent resin transfer media in the now growing field of resin infusion. The problem we had was this emerging segment of the industry was and still is in a quagmire over patents. Before Colebond proceeded into the market we needed to better understand the patents surrounding the infusion process.

Before I proceed, a brief word on patents is in order. A patent is granted to someone who makes a significant improvement to the current state of the art. A patent, if granted, allows for what is in effect a legal monopoly for a defined period of time (typically 17 years). Having a legal monopoly is great, but you must remember that this is a two-way deal. In order to get the patent, the inventor must disclose to the world the entire invention, and the technology is free for use without restriction after the patent expires. So the exercise here is not to prove current patents invalid, but to understand the prior art and how recent patents have improved the art.

I was amazed on reviewing patents as to how long ago closed molding was invented. One early patent was particularly interesting; it was by Irving Musket, dated 1950 and is US Patent #2,495,640. As it turns out, Musket has many patents around composites and resin technology extending into the 60's. Early resin technology suffered from air inhibition, so early resin systems did not cure properly unless a closed mold was used. The invention of resins that could cure when exposed to air was an improvement made in the 60's. As one tool surface could now be eliminated, open molding was born. It is ironic that today we are trying to move back to closed molding to reduce HAP's, and improve process and product.

The 1950 Musket patent looks to me to be the one that defines closed molding. Figures 1-4 show the essence of the patent. Figure 1 shows two matched tool surfaces with dry reinforcement, the top flange of the tool vents to the atmosphere. Resin is pumped into the bottom of the tool and is injected into the part, while air vents out the flange. This is Resin Transfer Molding (RTM). Figure 2 shows the same tool inverted; now the flange is immersed in a resin bath and a vacuum is drawn on the high point of the tool while resin is sucked into the reinforcement. This is VARTM or infusion. Figure 3 shows compression molding. Here resin is poured into the mold, and reinforcement and the tool are pressed into the tool. For those that have done compression molding, you know that to get good wet out, you must sometimes put resin on both the top and bottom of the reinforcement layer. This trick is shown in Figure 4. So as I see it, Musket, in a single patent, has defined RTM, VARTM, and Compression molding.

Another early patent I found interesting was by Smith, 1959 (Patent # 2,913,036). This patent is much more like today's modern infusion, in that it relies on a vacuum bag as a tool surface. The patent is described by using a swimming pool as the part being produced. Figures 5-9 show the elements of the patent. The part is produced over a male mold, dry reinforcement is laid over the mold, a vacuum bag is placed over the tool, resin is introduced into the perimeter trough system in the tool, and vacuum is used to

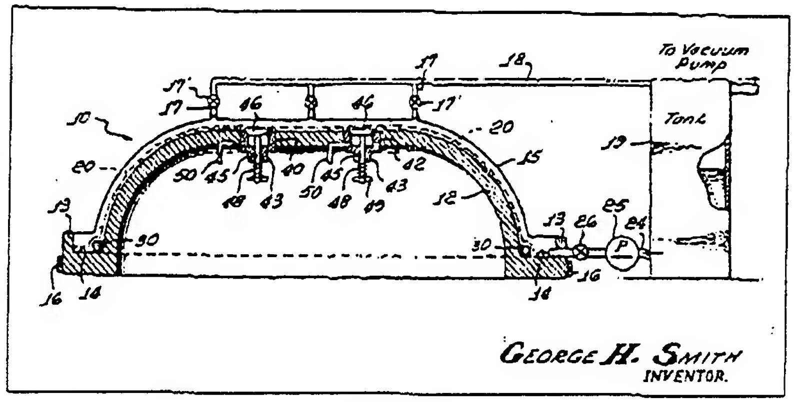

Figure 6

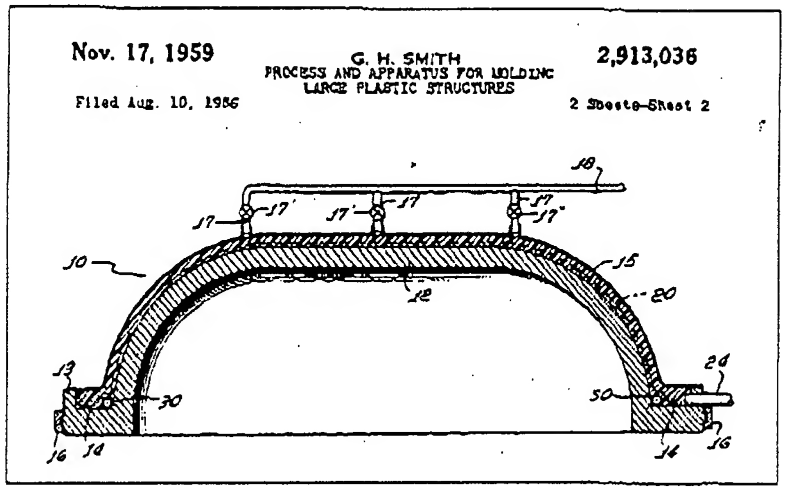

Figure 7

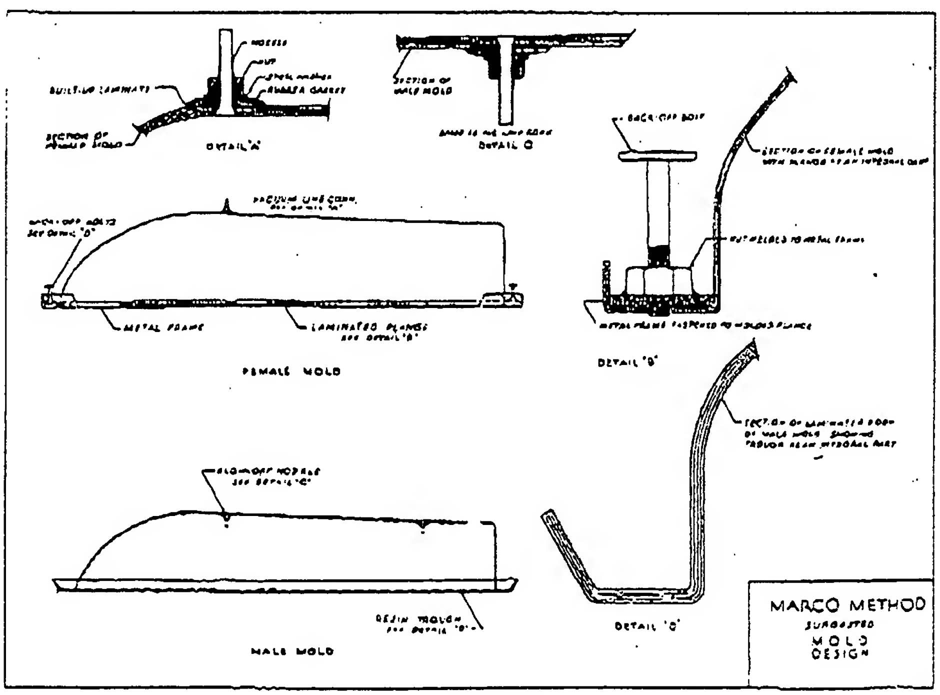

Figure 8

draw the resin into the reinforcement. What distinguishes this patent is the innovative use of frame stiffeners as resin transfer pathways. Smith realized that filling the part by using only the trough as a feeder would be very slow, if even possible. To speed filling, Smith uses bent pieces of perforated metal (Figure 9) and places these vertically around the perimeter of the part (Figures 5 and 6). The half round perforation is covered with additional reinforcement. When a vacuum is placed on the bag, the resin can now feed up from the trough into the channel, then infuse into the surrounding laminate. The result is a part that fills quickly and has the nice advantage of having integrated framing.

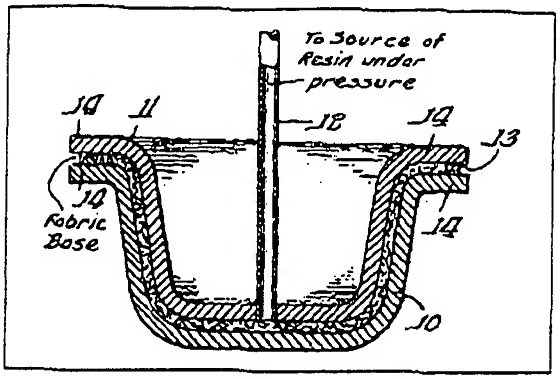

Figure 9

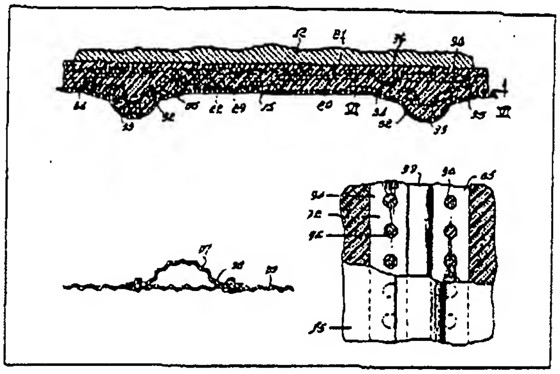
Figure 10

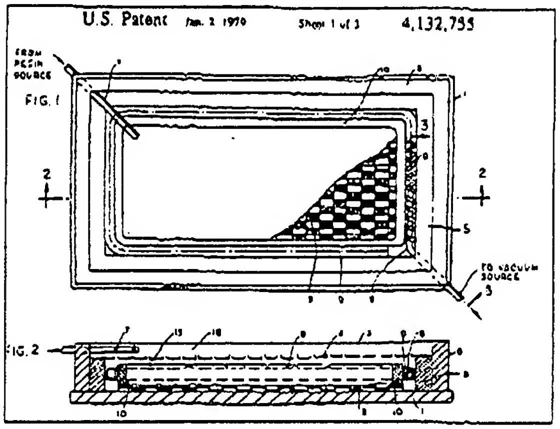

Figure 11

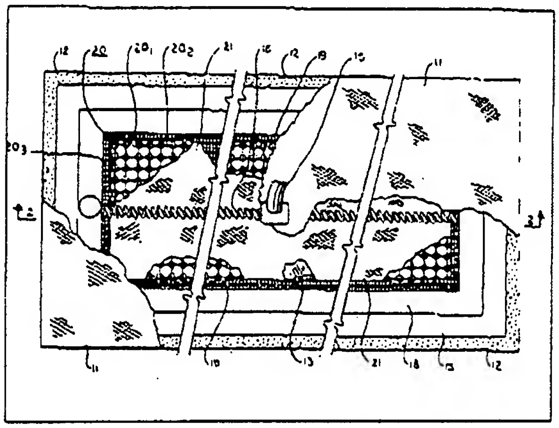
Figure 12

Bob Lacovara, CFA Technical Director, was able to find another interesting document on early closed molding. This was a technical publication from Celanese from the late 1950's or early 1960's. The publication details the Marco Method. Marco Chemical Company was one of the pioneers in the commercial fabrication of FRP parts. The Marco Method appears to be a combination of the elements of Musket and Smith. Figure 10 is a section from the publication. The example is a small boat hull. They used matched metal tools in this example. Reinforcement is draped over a male tool, note that the male tool has a large reverse flange that forms a trough around the perimeter. The female tool goes over the male tool and extends down into the trough. Resin is then poured into the tough and a vacuum is applied up at the keel of the female tool. The vacuum pulls the resin into the reinforcement, thus wetting out the part. I found it particularly interesting to see them detail in the text that the vacuum line must have a trap for the resin and that if the trap fills you can empty it back into the tough. This is the basic concept of the recirculation molding process that we are using today for the Navy; someone beat me to it before I was even born!

Moving forward to a recently expired patent, Figure 11 shows patent 4,132,755 by Johnson. Johnson makes use of a surface media to aid in the flow of resin. Resin is introduced along an edge of the part, while vacuum is applied at another edge. Resin flows across the media and down into the reinforcement, displacing void with resin. We are getting close to the practice disclosed by Seemann. The difference is that Seemann made a major improvement over Johnson in the way of resin distribution systems. Seemann, in his 1990 patent (Patent # 4,902,215), shows the use of a surface infusion media with

("Closed Molding Infusion..." continued on p. 82)

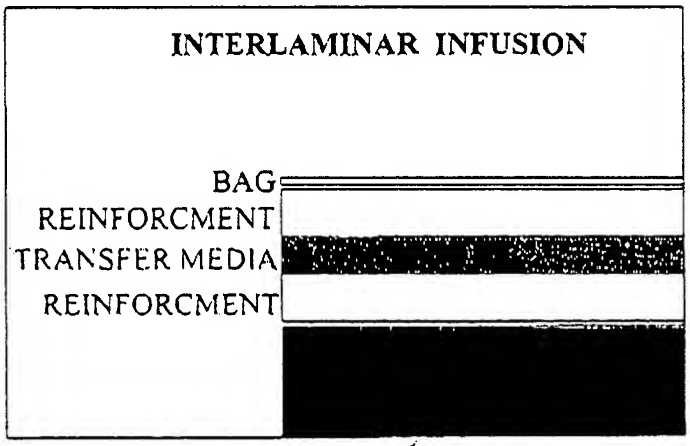

Figure 13

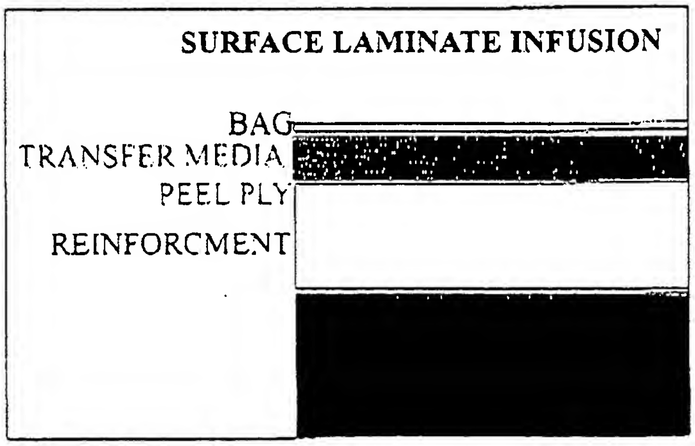

Figure 14

("Closed Molding Infusion" from p. 59)

one important addition, the use of a hose or channel-way that crosses over the top of the media (see Figure 12). The use of this hose system allows surface infusion to be performed much more efficiently then using on the edge of the tool as a feeder. This important practical improvement is the heart of the patent.

The Infusion Media we were helping Colebond develop would work well for surface infusion using the expired Johnson patent or the current Seeman patent. We also found that the media worked great in VARTM using our recirculation technique. After a review of the prior art and the expired patents, it was decided that interlaminar infusion could be a beneficial process for much of the industry, and would be less subject to current patent restrictions. The concept is to use an infusion media on the neutral axis instead of a surface media. Figures 13 and 14 show diagrammatically the difference between surface and interlaminar infusion.

There are several very important differences between interlaminar and surface infusion. In surface infusion, a peel ply layer separates the media from the laminate. After the part infuses, the bag, media and peel ply are all disposed of. So all of the resin that is in the media is also lost as waste. In interlaminar infusion, the laminate itself is used as the transfer media, so the media and associated resin that has to be disposed of with surface infusion becomes part of the laminate with interlaminar infusion. Section restoration is another area that differs from Surface and Interlaminar infusion. With Infusion, the force of the vacuum compresses the dry reinforcement, and the result is a nice high fiber content laminate, but the loss of thickness can be very severe. Many laminates are dominated by flexural loading, and a small decrease in thickness can result in a large drop in bending stiffness. With a single skin laminate and surface infusion, you would probably need to add additional layers of glass restore the thickness. The end result, depending on what you pay for resin and glass, can be a more expensive higher density laminate with more glass layers and weight then you had with hand lay up. By using interlaminar infusion the media is placed on the neutral axis, thus helping to restore the laminate thickness that is lost due to compression by the vacuum bag. In essence, what we are doing is making a solid sandwich with high fiber content skins and a resin rich neural axis. It is important to realize that the laminate properties of interlaminar infusion are different than surface infusion. In Part 2 of this paper, I will present data on the mechanical properties of laminates produced using hand lay up, surface infusion, and interlaminar infusion.

One other aspect to open technology approaches to infusion is with regard to the distribution system. The use of hose systems as is taught with the Seemann patent is not recommended unless you have a valid SCRIMP license. What can you use? I look to the Smith patent of 1959. Smith taught us to use framing systems as feeders using infusion. So the key is to have your framing system be your feeder system. The way I see it, this is better anyway. Why not co-infuse your frames at the same time you do the base laminate? The advantages are numerous; the most significant of which is primary bonding, reduced labor, and lets not forget Smith 1959! Figures 15 and 16 show a laminate being produced using interlaminar infusion with integrated framing. In this case a preform frame with the feeder system incorporated into the preform is used as the combined stiffener and resin feeder.

Interlaminar or Surface infusion, Patented processes, or open technology approaches—you have the choices. Bill Seemann and many others have made significant improvements to infusion as is evidenced by the long string of recent patents surrounding infusion. Bill Seemann deserves a lot of credit for advancing the infusion process and our awareness of what infusion can do. Before delving

Figure 15

The end result, depending on what you pay for resin and glass, can be a more expensive higher density laminate with more glass layers and weight then you had with hand lay up.

into infusion. I suggest that you discuss the process with the current patent holders and see what their processes have to offer. If you think you can benefit from the use of a current valid patent, you should approach the owners of the patent and discuss license arrangements. You are also free to use the teachings of expired patents such as Musket, Smith and Johnson for your manufacturing, without having to enter into any license agreements. The choice is yours.

Part 2 of this series will show the results of ongoing mechanical tests of laminates produced using hand lay up, surface infusion and interlaminar infusion. Part 3 of this series will discuss Recirculation Molding, an open technology approach to VARTM. CF

I would like to recognize the efforts of Mr. Steve Linder, Office of Naval Research, US Navy; Mr. Andre Cocquyte, GRP Guru; Mr. Gordon Lacy, Gregory Marshall Naval Architect Ltd.; Mr. Bob Lacovara, CFA; and Mr. Tom Robrecht, Colebond Inc. with their assistance in providing information and for their commitment to helping advance open technology approaches to composites manufacturing.

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Figure 16